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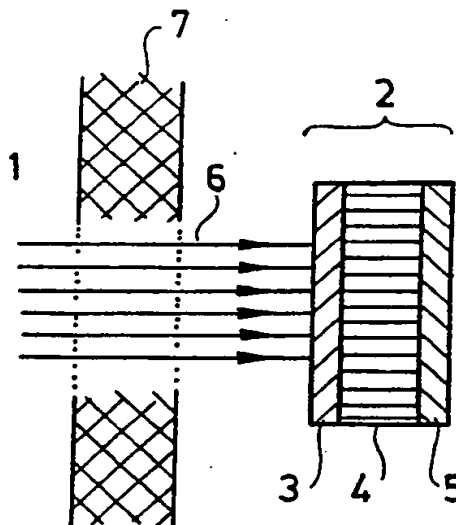
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁵ : G21G 1/06</p>	<p>A1</p>	<p>(11) International Publication Number: WO 90/06583 (43) International Publication Date: 14 June 1990 (14.06.90)</p>
<p>(21) International Application Number: PCT/HU89/00054 (22) International Filing Date: 20 November 1989 (20.11.89) (30) Priority data: 6077/88 28 November 1988 (28.11.88) HU (71)(72) Applicant and Inventor: TELEKI, Péter [HU/HU]; Bocskai u. 30, H-2400 Dunaújváros (HU). (74) Agent: DANUBIA; P.O. Box 198, H-1368 Budapest (HU). (81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), LU (European patent), NL (European patent), SE (European patent), SU, US.</p>		<p>Published With international search report.</p>

(54) Title: METHOD OF UTILIZING THE (n, gamma) REACTION OF THERMAL NEUTRONS



(57) Abstract

The invention refers to a method of utilizing the (n, gamma) reaction of thermal neutrons, comprising the steps of arranging a target (2) before a source (1) of thermal neutrons, the target (2) having a front surface directed to the source (1) of the thermal neutrons and a rear surface lying behind the front surface, preparing the target (2) with a basic metal body (4) made of ^{70}Yb and/or ^{74}W , producing by the means of the thermal neutrons a metallic mixture including the basic metal(s) and at least one of the pairs of metals $^{71}\text{Lu} + ^{72}\text{Hf}$ and $^{75}\text{Re} + ^{76}\text{Os}$ and storing the metallic mixture for reducing its nuclear activity.

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- 1 -

METHOD OF UTILIZING THE (n, gamma) REACTION
OF THERMAL NEUTRONS

5

FIELD OF THE INVENTION

10 The present invention refers to a method of utilizing the (n, gamma) reaction of thermal neutrons, wherein a target is arranged before a source of thermal neutrons. The method of the invention results in possibility of making use of the thermal neutron flux of a nuclear reactor, with disregard to the kind of the reactor, whereby the economy of operating of the different reactors can be highly improved. The proposed method can be realised with reactors of diverse kinds, e.g. with experimental reactors, energetic or boiler reactors etc.

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BACKGROUND OF THE INVENTION

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It is known from the literature that the (n, gamma) reaction can be applied for producing some isotopes. For example, the reaction

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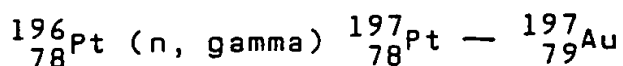


30

is the basis of generating the very important isotope of cobalt having mass number 60 which is widely used in the medicine and industry. In this process the end product is a substance showing high level of radioactivity (gamma-activity). This process may not be realised without special security measures.

35

The theory of atomic nuclei recites lots of theoretical and practical reactions for transforming chemical elements, i.e. atomic nuclei. In the handbooks e.g. the process



1 can be found for producing gold, wherein the half-period
of decay of the intermediate platinum isotope is relative-
ly short, about 20 hours. This way of producing gold is
very expensive and inconvenient: the substance at the be-
5 ginning of the process is twice so expensive than the gold
received. Another disadvantage of this process is that the
platinum isotope with mass number 196 amounts about 25.3 %
of the whole platinum mass and therefore a separate pro-
cess is necessary for yielding the gold.

10

SUMMARY OF THE INVENTION

The object of the present invention is to make use
of the thermal neutron flux of a reactor for producing non
15 radioactive materials, wherein no special security meas-
ures are to be taken.

The invention is based on the recognition that
ytterbium and tungsten can be transformed into a mixture of
different elements showing no or very low level radioacti-
20 vity by means of the thermal neutrons generated in each
radioactive reactor.

Hence, the invention proposes a method of utilizing
the (n, gamma) reaction of thermal neutrons of a reactor,
the method comprising the step of arranging a target di-
25 rected with its front surface to a source of thermal neu-
trons, especially a reactor, wherein according to the inven-
tion the target is consisted of ^{70}Yb and/or ^{74}W . It is
especially advantageous to apply before the target a plate
shaped body for slowing down the quick and/or the reactor
30 neutrons, consisted of ^{41}Nb for slowing down the reactor
neutrons and/or ^{59}Pr for slowing down the quick neutrons.
Of course, this moderator of neutrons can be made also of
beryllium. A beryllium plated can be applied also for cov-
35 ering the rear side of the target - this ensures reflec-
tion of the neutrons back to the target.

1 By the means of the method proposed by the inven-
tion about 30 % of the amount of ytterbium can be trans-
formed into lutetium and the same amount of tungsten into
rhenium. Above that about 20 % of tungsten transform into
5 osmium. The metals received, i.e. lutetium, rhenium and
osmium are much more expensive than the input metal of the
process and can be separated therefrom by simple thermal
processing because of considerable differences in the res-
pective melting points.

10 BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further disclosed in more de-
tail by way of example and with reference to the attached
15 drawings. In the drawings

FIG. 1 shows the cross-section of a target applied
in realising the present invention.

20 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the vicinity of a reactor 1 limited by a wall 7
a target 2 is arranged in an appropriate place. The target
2 consists of a front layer 3 forming a moderating body, a
metal plate 4 including ytterbium and/or tungsten to be
25 transformed and a rear reflecting layer 5. The front layer
3 is made of $_{41}\text{Nb}$ and/or $_{59}\text{Pr}$. If necessary, $_{4}\text{Be}$ can be
applied to. The mentioned metals slow down the flux of the
neutrons leaving the interior of the reactor 2. The ref-
lecting layer 5 covering the rear surface of the metal
30 plate 4 reflects the neutrons back to the metal plate 4.
The target 2 is arranged to be irradiated by a thermal
neutron flux 6 and the front layer 3 receives the neu-
trons before entering the metal plate 4.

The neutron flux 6 can be directed to the target 2
35 through the wall 7 of the reactor 1 in a known way, e.g.

1 by the means of a window prepared in the wall 7.

As mentioned, the metal plate 4 is made of ytterbium and/or tungsten. The irradiation of this plate carried out by the thermal neutrons generated by the reactor 1 or produced by the front layer in a (n, 2n) reaction should result in an alloy like mixture consisting of the following metals (the composition is given with approximate data):

a) on the basis of ytterbium:

37 112 101.4 127
 10 $^{70}\text{Yb} + ^{71}\text{Lu} + ^{72}\text{Hf} (+ ^{69}\text{Tm})$
 60 % 30 % 10 % 0.1 %

b) on the basis of tungsten:

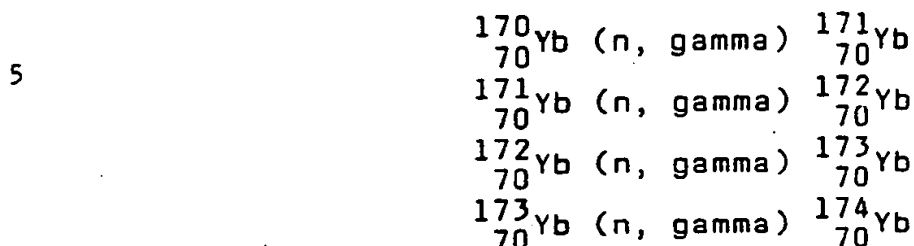
19.2 86 15.3 21
 15 $^{74}\text{W} + ^{75}\text{Re} + ^{76}\text{Os} (+ ^{73}\text{Ta})$
 50 % 30 % 20 % 0.1 %

The line over the signs of the elements give the value of the cross-section for the process expressed in barns.

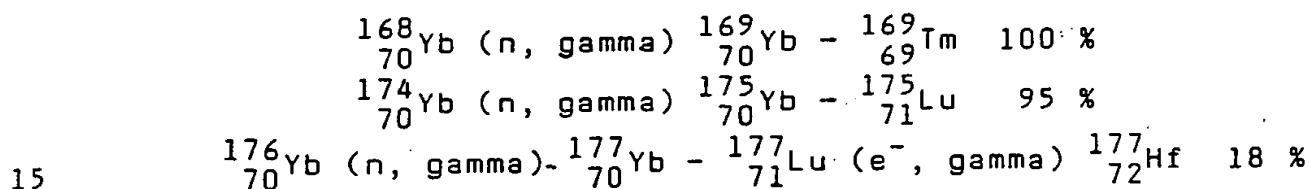
20 When taking ytterbium, the metal includes the following isotopes:

	Mass number of ^{70}Yb	Proportion	Half-period of decay	Kind of decay		
25	167	0.135 %	19 minutes	gamma, K		
	168					
	169					
	170					
	171					
30	172	21.82 %	31.8 days			
	173	16.13 %				
	174	31.84 %				
	175	12.73 %			101 hours	e^- , K
	176					
35	177		1.9 hours	e^- , K		

1 From this table it follows that about 55.3 % of all
(n, gamma) reactions do not result in any change of the
atomic number. These reactions are:



10 The following reactions result in transformation
of elements:



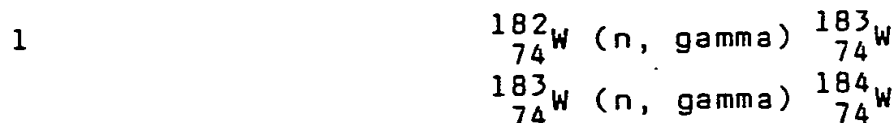
The percentage values means the proportion of the
given stable isotope in the metal mentioned.

The process of stabilization of ${}^{177}_{71}\text{Lu}$ is characteris-
ed by the half-period 6.75 days.

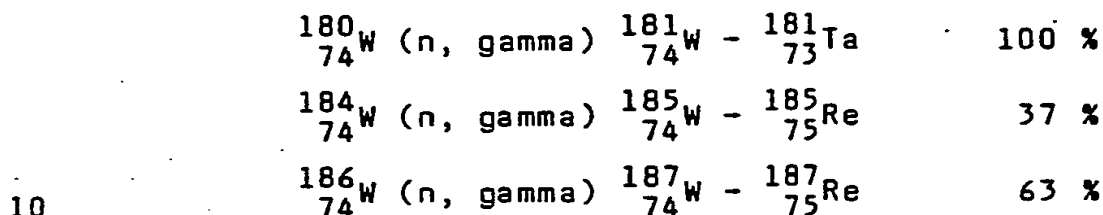
20 When taking tungsten, the metal includes the follow-
ing isotopes:

	Mass number of $_{74}\text{W}$	Proportion, %	Half-period of decay	Kind of decay	
25	179	0.135	40 minutes	gamma, K	
	180		145 days	gamma, K	
	181				
	182				
30	183	26.41	73.2 days	e^- , gamma	
	184	14.40			
	185	30.645			
	186	28.41			
	187	24.0 hours			e^- , gamma

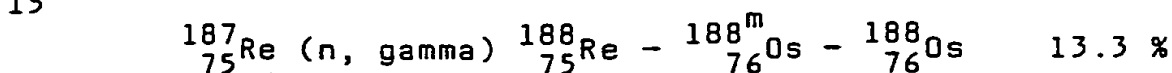
35 From this table it follows that about 40.8 % of all
(n, gamma) reactions do not result in any change of the
atomic number. These reactions are:



5 The following reactions result in transformation of elements:



15 In normal circumstances, ${}^{187}_{75}\text{Re}$ is transformed into ${}^{187}_{76}\text{Os}$ characterised by half-period about $5 \cdot 10^{10}$ years by weak e^- radiation. In a (n, gamma) reaction, however another process dominates:



20 The half-period of rhenium is 18 hours, the isomeric osmium nucleus shows half-period 26 days. In these conditions the rhenium ${}^{185}_{75}\text{Re}$ can be also activated and in decay processes (e^- , gamma, K) it can be transformed partly into tungsten, partly into osmium: a dominate part, however, remains unchanged in form of rhenium.

25 In both series of reactions the gamma radiation coming into being is a low energy, low intensity weak radiation.

30 The metallic mixtures prepared by the invention require at least 1/2 year storage before further processing. During this time the radiation level of the mixture falls under a maximum level allowed by the rules.

35 When considering the basic metal and the metallic components produced by the method of the invention it can be stated that they are capable of bearing high thermal load and the alloy received in the process is stable. The melting points of the metals in the mixtures mentioned are the following:

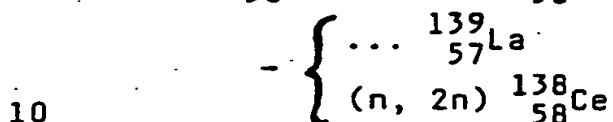
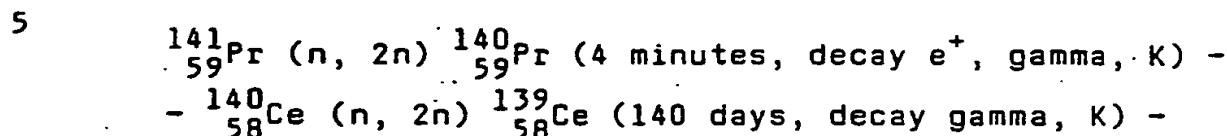
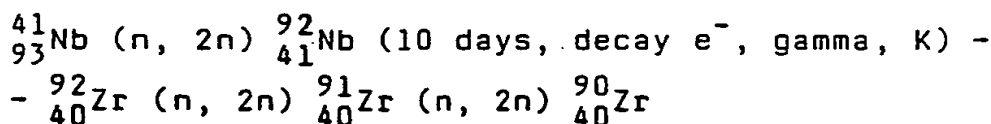
1	^{70}Yb	+	^{71}Lu	+	^{72}Hf	+	^{69}Tm
	824 °C		1652 °C		2222 °C		1545 °C
	^{74}W	+	^{75}Re	+	^{76}Os	+	^{73}Ta
5	3410 °C		3180 °C		2700 °C		2996 °C

In realising the method of the invention it is advantageous to arrange the target 2 in the proximity of the active zone of the reactor, but under the condition that the target can not be the object of radiation comprising charged particles and fission products. If these factors are excluded the only disturbing effects follow from the gamma radiation of the reactor and the flux of quick neutrons emitted from the reactor. In both cases the loss of neutrons by the nucleus can follow in (gamma, n) and (n, 2n) reactions, however, these are low probability processes. Therefore the only requirement is to moderate the quick neutrons, because the reactions with loss of neutron constitute a part of the reactions which hardly play important rule.

The reactor neutrons show a wide spectrum with average energy 0.72 MeV (the flux may contain also neutrons with energy 20 MeV), therefore it is advantageous to slow down (moderate) the reactor neutrons and the quick neutrons by the means of (n, 2n) reactions whereby the yield of neutrons can be increased. The beryllium moderator is in this case a further element after that applied for slowing down the reactor and quick neutrons.

The reactions of the reactor neutrons are characterized by small cross-section. Hence, they can be slowed down by means of the reaction $^{93}_{41}\text{Nb}$ (n, 2n) $^{92}_{41}\text{Nb}$. A very effective reaction for slowing down the quick neutrons having energy in the range about 14 to 15 MeV is based on praesodymium: $^{141}_{59}\text{Pr}$ (n, 2n) $^{140}_{59}\text{Pr}$. The processes mentioned result in increased yield of neutrons. The advantageous character of these reaction can be seen from the following

1 scheme of reactions:



Other reaction scheme are possible with low probability, because of the short half-period.

The target 2 includes advantageously a rear reflecting layer 5 for reflecting back the neutrons. This layer can be made of beryllium (${}_4\text{Be}$).

The plate 4 of the target 2 is arranged preferably so that the neutron flux of the reactor falls under right angle (90°) on its surface.

Summarizing, the method of the invention should be realised with a target 2 including after the reactor a layer made of ${}_{59}^{141}\text{Pr}$ and/or ${}_{93}^{41}\text{Nb}$, a moderator (of ${}_4\text{Be}$), the metal plate 4 made of ${}_{74}\text{W}$ and/or ${}_{70}\text{Yb}$ and a mirror layer (rear reflecting layer 5, made of ${}_4\text{Be}$). The beryllium can be preferred because it is a neutron source under influence of the gamma radiation emitted by the reactor, with the following reactions:



wherein the neutrons at the output have energy 110 keV.

The process of the invention can be applied for preparing catalyzer substances — this improves the economy of operating a reactor. No specific security means or expenses are necessary. The metal mixtures can be separated into components according to the known thermal techniques or applied as alloys.

1

CLAIMS:

1. Method of utilizing the (n, gamma) reaction of
5 thermal neutrons, comprising the step of arranging a target before a source of thermal neutrons, the target having a front surface directed to the source of the thermal neutrons and a rear surface behind the front surface,
characterized in the further steps of
10 - preparing the target with a basic metal body made of at least one metal selected from the group including ^{70}Yb and ^{74}W ,
- producing by the means of thermal neutrons a metallic mixture including the basic metal(s) and at least one
15 pair of metals selected from the group including $^{71}\text{Lu} + ^{72}\text{Hf}$ and $^{75}\text{Re} + ^{76}\text{Os}$ and
- storing the metallic mixture for reducing its activity.
2. The method as set forth in claim 1, characterized in preparing the basic metal body in the form
20 of a plate and arranging it perpendicularly to the flux of the thermal neutrons.
3. The method as set forth in claim 1 or 2, characterized in the step of arranging on the front surface of the basic metal body a layer for slowing down fast
25 and reactor neutrons by the means of (n, 2n) reactions, the layer consisting of at least one metal selected from the group including ^{41}Nb and ^{59}Pr .
4. The method as set forth in any of claims 1 to 3, characterized in the step of arranging at least
30 one beryllium moderating layer on at least one of the front and rear surfaces of the target.
5. The method as set forth in any of claims 1 to 4, characterized in the further step of carrying out thermal decomposition of the metallic mixture after the
35 storing period.

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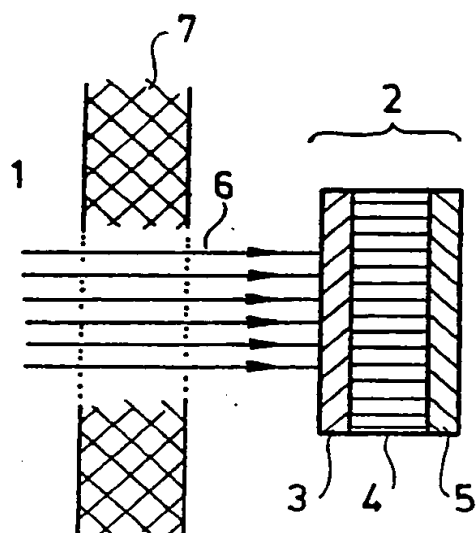


Fig. 1

INTERNATIONAL SEARCH REPORT

International Application No. PCT/HU 89/00054

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁵ According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁵ : G 21 G 1/06																										
II. FIELDS SEARCHED <div style="text-align: center; font-size: small;">Minimum Documentation Searched ⁷</div> <table style="width: 100%; border: none;"> <tr> <td style="width: 20%; border: none;">Classification System</td> <td style="border: none;">Classification Symbols</td> </tr> <tr> <td style="border: none; padding: 5px;">Int.Cl.⁵:</td> <td style="border: none; padding: 5px;">G 21 G 1/06, 1/08, 4/02; H 05 H 6/00, G 21 K 5/08, G 01 T 1/29</td> </tr> </table> <div style="text-align: center; font-size: x-small;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸</div>			Classification System	Classification Symbols	Int.Cl. ⁵ :	G 21 G 1/06, 1/08, 4/02; H 05 H 6/00, G 21 K 5/08, G 01 T 1/29																				
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III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹ <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%; font-size: x-small;">Category ¹⁰</th> <th style="width: 70%; font-size: x-small;">Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²</th> <th style="width: 20%; font-size: x-small;">Relevant to Claim No. ¹³</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">A</td> <td>GB, A, 1 075 411 (NRA) 12 July 1967 (12.07.67), see claims 7,9.</td> <td style="text-align: center;">(1-3)</td> </tr> <tr> <td style="text-align: center;">A</td> <td>US, A, 4 055 686 (STEINBERG) 25 October 1977 (25.10.77), see claims 2,12; column 6, line 49.</td> <td style="text-align: center;">(1-3)</td> </tr> <tr> <td style="text-align: center;">A</td> <td>GB, A, 974 622 (UNITED KINGDOM ATOMIC ENRGY) 11 November 1964 (11.11.64).</td> <td style="text-align: center;">(1-3)</td> </tr> <tr> <td style="text-align: center;">A</td> <td>DE, A, 1 908 144 (STARK) 11 September 1969 (11.09.69), see claims 2,3.</td> <td style="text-align: center;">(1,2,4)</td> </tr> <tr> <td style="text-align: center;">A</td> <td>DE, A1, 2 941 096 (PHILIPS) 30 April 1980 (30.04.80), see fig. 1b; claims 1,3.</td> <td style="text-align: center;">(1-3)</td> </tr> <tr> <td style="text-align: center;">A</td> <td>GB, A, 440 023 (SZILARD) 12 December 1935 (12.12.35), see page 6, lines 110-130; page 9, line 113 - page 10, line 16.</td> <td style="text-align: center;">(1,4,5)</td> </tr> <tr> <td style="text-align: center;">A</td> <td>GB, A, 1 243 262 (NATIONAL RESEARCH DEVELOPEMENT) 18 August 1971 (18.08.71), see page 2, lines 86, 89; claims 3,8.</td> <td style="text-align: center;">(1,2,4)</td> </tr> </tbody> </table> <div style="font-size: x-small; margin-top: 10px;"> <p>¹⁰ Special categories of cited documents: ¹¹</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"A" document member of the same patent family</p> </div>			Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³	A	GB, A, 1 075 411 (NRA) 12 July 1967 (12.07.67), see claims 7,9.	(1-3)	A	US, A, 4 055 686 (STEINBERG) 25 October 1977 (25.10.77), see claims 2,12; column 6, line 49.	(1-3)	A	GB, A, 974 622 (UNITED KINGDOM ATOMIC ENRGY) 11 November 1964 (11.11.64).	(1-3)	A	DE, A, 1 908 144 (STARK) 11 September 1969 (11.09.69), see claims 2,3.	(1,2,4)	A	DE, A1, 2 941 096 (PHILIPS) 30 April 1980 (30.04.80), see fig. 1b; claims 1,3.	(1-3)	A	GB, A, 440 023 (SZILARD) 12 December 1935 (12.12.35), see page 6, lines 110-130; page 9, line 113 - page 10, line 16.	(1,4,5)	A	GB, A, 1 243 262 (NATIONAL RESEARCH DEVELOPEMENT) 18 August 1971 (18.08.71), see page 2, lines 86, 89; claims 3,8.	(1,2,4)
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IV. CERTIFICATION <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;">Date of the Actual Completion of the International Search</td> <td style="width: 50%; border: none;">Date of Mailing of this International Search Report</td> </tr> <tr> <td style="border: none;">06 February 1990 (06.02.90)</td> <td style="border: none;">07 February 1990 (07.02.90)</td> </tr> <tr> <td style="border: none;">International Searching Authority</td> <td style="border: none;">Signature of Authorized Officer</td> </tr> <tr> <td style="border: none;">AUSTRIAN PATENT OFFICE</td> <td style="border: none;"> </td> </tr> </table>			Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	06 February 1990 (06.02.90)	07 February 1990 (07.02.90)	International Searching Authority	Signature of Authorized Officer	AUSTRIAN PATENT OFFICE																	
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International Searching Authority	Signature of Authorized Officer																									
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	W.EPPRECHT, "Werkstoffkunde der Kerntechnik", published 1961, Birkhäuser Verlag, Basel und Stuttgart, see pages 221,323.	(1)
A	K.H.HOCKER, K.WEIMER, "Lexikon der Kern- und Reaktortechnik.", published 1959, Franckh'sche Verlagshandlung W.Keller, Stuttgart, see page 635.	(1)

Anhang zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentedokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

Annex to the International Search Report on International Patent Application No. PCT/HU 89/00054

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned International search report. The Austrian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Annexe au rapport de recherche internationale relatif à la demande de brevet international n°.

La présente annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche internationale visé ci-dessus. Les renseignements fournis sont donnés à titre indicatif et n'engagent pas la responsabilité de l'Office autrichien des brevets.

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Mitglied(er) der
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For more details about this annex: see Official Journal of the European Patent Office, No. 12/82.